Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matters of	)	
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Mitigation of Orbital Debris in the New Space Age	)	IB Docket No. 18-313
	)	
Mitigation of Orbital Debris	)	
	)	
Notice of Proposed Rulemaking and Order on Reconsideration	)	

REPLY COMMENTS OF SWARM TECHNOLOGIES INC.

Swarm Technologies Inc. ("Swarm") submits reply comments in response to the Notice of Proposed Rulemaking ("Notice") to amend Federal Communications Commission ("FCC" or "Commission") Rules concerning mitigation of orbital debris.[1] Swarm herein lends its voice to the chorus of space industry interests already expressing support for data-driven rules to mitigate orbital debris with a regulatory framework that promotes innovation in space. Swarm commends the Commission for taking a thoughtful approach to addressing orbital debris. We encourage additional cooperation between the Commission and the satellite industry to foster a regulatory framework based on data that recognizes the innovation occurring in the "new" space industry.

I. Swarm Background

Founded in 2016, Swarm is a California-based satellite company committed to providing accessible, low-cost global connectivity. Specifically, Swarm intends to deploy a constellation of

[1] *See Mitigation of Orbital Debris in the New Space Age; Mitigation of Orbital Debris*, Notice of Proposed Rulemaking and Order on Reconsideration, IB Docket No. 18-313, 33 FCC Rcd 11352 (2018) ("*NPRM*").

two-way communications satellites utilizing Very High Frequency ("VHF") band frequencies.[2] Through its planned constellation, Swarm will offer two-way communications to allow end users to send and receive data anywhere in the world, including remote underserved or altogether unserved communities. Moreover, Swarm intends to leverage advances in small satellite design and the increased availability of launch opportunities for small satellites to bring our proposed non-geostationary satellite system into service promptly, and to begin serving customers far faster than alternative networks using larger spacecraft and traditional launch vehicles.[3]

With respect to orbital debris mitigation, Swarm's co-founders, Dr. Sara Spangelo and Dr. Benjamin Longmier, worked at the National Aeronautics and Space Administration's ("NASA's") Jet Propulsion Laboratory ("JPL") and NASA's Johnson Space Center, respectively, supporting a diverse range of space missions. This experience gives Swarm's senior leadership an intimate understanding of orbital debris and related issues. Swarm offers insights based on this experience herein.

II. Industry and Governmental Commenters Support Data-Driven Rules

The record shows broad consensus for data-driven rules designed to mitigate orbital debris while maintaining the innovative space economy that United States' leadership has fostered.[4] The

[2] Application of Swarm Technologies Inc. for Authority to Launch and Operate a Non-Voice, Non-Geostationary Lower Earth Orbit Satellite System in the Mobile-Satellite Services, IBFS File No. SAT-LOA-20181221-00094, (filed Dec. 21, 2018) ("*Swarm Application*"), at attachment Narrative Exhibit, 1-2 ("*Application Narrative*").

[3] Id.

[4] AT&T Comments at 1 (Commission should decline to adopt rules unless absolutely necessary); Boeing Comments at ii (highly technical issues should be informed by expertise and coordination to prevent disadvantaging U.S. satellite operators); EchoStar Comments at 4 (Commission should defer to other expert agencies on technical criteria while focusing on the Commission's core mission); Astrosale Holdings Comments at 4 (Commission should focus rules to promote behaviors by deferring to industry best practices to prevent overregulation); Intelsat Comments at 1-3 (Commission should foster innovation by not duplicating other agencies technical expertise); Lockheed Martin Corporation Comments at 2-3 (Rules must enable a comprehensive risk mitigation framework for the space environment – without unnecessarily constraining the innovations and opportunities); WorldVu Comments at i-iii (A well-integrated regulatory framework is necessary for continue commercial success in space and the Commission should ensure a comprehensive, data-driven approach across the US and International Governments); ORBCOMM

planning and development of any space mission, let alone proposed constellations featuring hundreds of spacecraft, requires regulatory certainty and licensing requirements that can be met through objective technical submissions and data analysis. The Commission's thoughtful approach in comprehensively reviewing its orbital debris rules is the right first step.[5] To develop rules that mitigate orbital debris, the Commission should focus on rules that have objective criteria and a data-driven analytical focus.

Since the rules adopted in 2004, new tools that facilitate modeling based on real data are either already available in 2019, or will be available in the near future. For example, LeoLabs, a California based entity, has already begun deploying and making data available from a worldwide network of ground-based, phased-array radars that enable high-resolution data on objects in LEO.[6] Alternatively, as the Commission itself explains, the United States Air Force ("Air Force") will also have access to data sets from its own "Space Fence" at some point in 2019.[7] Specifically, the Space Fence will employ "Gallium Nitride ("GaN") powered S-band ground-based radars to provide the Air Force with uncued detection, tracking and accurate measurement of space objects, primarily in low-earth orbit."[8] This ability to model the space environment allows operators the necessary inputs to produce highly detailed and robust orbital risk and debris assessments. The

Comments at 1-6 (Commission should let other expert agencies take the lead with technical rules, with the Commission assuming a complementary role within its licensing authority); SpaceX Comments at i-iv (The Commission's priorities should be achieved through clear and enforceable rules with objective and demonstrable data requirements); Viasat Comments at 1-2 (The Commission should adopt rules consistent with international standards that allow compliance through clear technical and other data standards).

[5] *NPRM* at para. 3.

[6] LeoLabs, *Leolabs Platform for Operators and Developers*, https://platform.leolabs.space/ (last visited May 1, 2019).

[7] *NPRM* at para. 26.

[8] Lockheed Martin, *Space Fence*, https://www.lockheedmartin.com/en-us/products/space-fence.html (last visited May 1, 2019); Lockheed Martin Comments at 10-12 (explaining the Air Force's efforts to track space objects).

Commission's rules should focus on this type of verifiable information when reviewing applications and adopt corresponding rules that can be met through objective, empirical data disclosures.

Both SpaceX and NASA support data-driven rules with verifiable and enforceable standards.[9] The SpaceX and NASA comments demonstrate the technical approach that should be taken when developing rules governing spaceflight. Swarm concurs with the SpaceX proposal that any adopted regulation should be based on "performance-based metrics that are both verifiable and enforceable."[10] Swarms joins SpaceX in cautioning against ex ante prescriptive regulations that are not verifiable by the Commission or operators.[11] For example, a potential 0.01% collision risk limit requires a number of assumptions that are "extremely sensitive" to input parameters that cannot be readily tested on Earth, like on-orbit impact velocities above 8 km/s or accidental explosion risk.[12] The Commission should be sensitive to specific metrics that will promote computer modeling solutions and not effectuate real-world changes. Further, the rules should favor transparency and operator disclosures that are reviewed by the Commission with objective standards.[13] This is especially important when handling conjunctions and debris mitigation planning that require coordination between operators and government actors.[14] Clear standards in the types of disclosures, how they should be coordinated, and what steps are expected will promote the healthy exchange of information between relevant parties.

[9] SpaceX Comments at 9-16; NASA Comments at 1, para. 2.

[10] SpaceX Comments at 9.

[11] Id. at 10-12.

[12] Id. at 11-12.

[13] Id. at 13.

[14] Id.

Additionally, Swarm agrees with NASA's comments that implementation of extremely specific regulations present "difficult technical problem[s]."[15] The required analysis to produce a 0.001% collision risk probability or even simply quantifying the difference between catastrophic and non-catastrophic collisions require detailed assumption explanations.[16] Compliance with such rules should be based on these detailed explanations and the Commission must provide objective criteria to meet when conducting these analyses.[17]

To achieve the Commission's goals of mitigating orbital debris, protecting operating satellites from unreasonable harm, and fostering innovative satellite technologies, the rules adopted in this proceeding should focus on verifiable information that can be demonstrated with objective, empirical data disclosures.

III. The Commission Should Adopt NASA's ISS Collision Avoidance Standards

NASA is the lead governmental agency on technical and practical knowledge regarding space and, in particular, scientific space missions.[18] The International Space Station ("ISS") represents one of the more than twenty high-value scientific spacecraft NASA operates in low-Earth orbit ("LEO").[19] While objects in LEO orbits pose a small quantifiable risk to these assets, NASA cautioned against a burdensome approach when evaluating spacecraft with proposed orbital decay through the ISS orbit.[20] Specifically, "spacecraft residing in circular orbits above the ISS, and decaying passively through the ISS altitude range, pose a small likelihood of requiring an ISS

[15] NASA Comments at 2, para. 4.

[16] Id. at 3, para. 4.

[17] Id.

[18] *See* NASA, *Apollo 11, July 20, 1969: One Giant Leap for Mankind*, link (July 20, 2017) (discussing the incredible achievement of the Apollo 11 moon landing).

[19] NASA Comments at 1.

[20] Id. at 3-4, para. 7.

debris avoidance maneuver."[21] NASA explained that elliptical orbits extend the timeframe that objects cross the ISS altitude, but even these threats are mitigated by spacecraft being able to maneuver.[22] To enact appropriate orbit selection rules, NASA suggests "establishing order of priority that would have the "transiting" spacecraft (with maneuvering capability) take an action to avoid a "stationary" spacecraft (which may or may not have maneuvering capability)."[23]

Swarm supports NASA's approach and would caution against prescriptive rules simply because a spacecraft's flight intersects with the ISS. Appropriate planning and maneuvering capabilities result in a limited and known risk to the ISS. Operators choose orbits and decommission plans based on a number of factors, and the Commission's rules should allow for continued flexibility in these decisions.

Protecting manned-spacecraft is everyone's top priority. Rules regarding orbit selection and spacecraft decommission plans should reflect the limited risk posed to the ISS by spacecraft passing through the ISS orbit.

IV. The Commission Should Focus on Trackability

The record shows broad support for trackability being the principal design question and not simply a size analog.[24] Either through passive (retro reflectors or increased radar signature designs) or active (transponders or beacons) means, the record's consensus agrees the focus should

[21] Id.

[22] Id. at 4, para. 7.

[23] Id.

[24] Josef Koller Comments (Aerospace Corporation) at 11-12; Astrosale Holdings Comments at 8-9; ORBCOMM Comments at 8-9; NASA Comments at 4-5; University Small-Satellite Researchers Comments at 5-7; Boeing Comments at 21-22; Intelsat Comments at 5; Iridium Comments at 7-8; Lockheed Martin Comments at 11-12; Keplerian Comments at 11-15; WorldVu Comments at 11-13; Maxar Technologies Inc. Comments at 1, 6; Commercial Smallsat Spectrum Management Association Comments at 10-11; Michael Maloney (Satellite Design for Recovery) Comments at 4.

be on the ability to identify, locate and track spacecraft. Size is not the defining characteristic in the ability to track a spacecraft, nor should the Commission focus its design rules around this limited criteria.

Swarm concurs with The Aerospace Corporation's comments regarding trackability of spacecraft.[25] Like The Aerospace Corporation, Swarm recognizes that the prior industry "rule of thumb" around 1U (10cm cubesat form factor) being the limit of trackability reflects certain assumptions.[26] These assumptions included altitudes of LEO or lower, optical tracking, and satellite design without additional signature enhancements.[27] However, the implementation of new technologies and standards (*e.g.*, the Space Fence) have dramatically improved trackability.[28] In some instances, the implementation of new technology may allow objects as small as 2 to 5 cm to be tracked in LEO altitudes without additional signature enhancements.[29] Accordingly, Swarm supports the recommendation that future orbital debris rules require trackability, while also permitting smaller satellite form factors pursuant to an affirmative demonstration that such spacecraft can be accurately tracked.[30]

Trackability can be improved through the use of active or passive signature enhancements. In fact, the passive radar retro reflectors used by Swarm's proposed satellites increase the radar signature of its ¼U satellites to more than the signature of the average 1U satellites in operation.[31]

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[25] Aerospace Corporation Comments at 11-12.

[26] Id. at 11.

[27] Id.

[28] Id.

[29] Id.

[30] Id. at 11-12.

[31] *Application Narrative*, at 6-7. Swarm 1/4U spacecraft also employ "turnstile" antennas that enhance their radar signature. Specifically, once on-orbit, Swarm satellites deploy antenna measuring 114 cm from tip to tip that significantly increase the radar cross-section of the Swarm satellites. *Swarm Application* at Exhibit C, 3-4.

These passive Van Atta array radar retro reflectors were developed by the Space and Naval Warfare ("SPAWAR") Systems Center in San Diego in cooperation with Swarm. The trackability analysis submitted to the FCC by Swarm demonstrates the capabilities of these passive signature elements and even enabled persistent detectability and tracking through the Space Surveillance Network's optical system.[32] This solution allows for the cost effective design of Swarm's satellites while ensuring ongoing operational safety and tracking capabilities.

The Commission should adopt rules representing the consensus in the record that trackability is the key characteristic of satellite design. Size alone is not indicative of trackability and should merely be one factor in assessing proposed spacecraft. Operators should be able to demonstrate the trackability characteristics of their spacecraft to meet an objective criteria. This criteria should focus on the ability to locate, identify and track spacecraft.

[32] Id. at 15, Exhibit B: Trackability Analysis.

V. Conclusion

Swarm commends the Commission on its thoughtful approach to updating its orbital debris rules. The Commission's focus on fostering continued innovation in space should be paired with a regulatory framework driven by object, data-based standards. Specifically, any orbital debris rules regarding orbit selection and decommission plans should reflect the small risk objects actually pose to the ISS. Further, any rules regarding satellite design should set object criteria for trackability that consider all data points informing the ability to locate, identify and track spacecraft. Swarm also reaffirms its support for the Commission's important role in the area of orbital debris mitigation. We also support the work of other expert agencies in developing the rules and best practices for the industry. The licensing process; however, should remain with the Commission to avoid redundant or parallel processing of necessary review and approvals.

Respectfully Submitted,

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